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JOHN W. FINCH, DIRECTOR

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COAL-MINE EXPLOSIONS IN WEST VIRGINIA, 1883-1933

BY

J. J. FORBES AND C. W. OWINGS

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By J. J. Forbes[2] and C. W. Owings[3]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6802."

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Although coal-mine explosions rank third among causes of underground fatalities, they receive more wide-spread attention than any other accidents in mines because frequently many persons lose their lives in a single disaster. Each bituminous coal-mine explosion endangers the lives of approximately 100 persons--the average number employed underground in a commercial mine. A critical analysis of coal-mine explosions in a restricted district gives a cross-section of relative existing explosion hazards, of common causes of ignitions of gas and dust, and of effective prevention measures. The Safety Division of the United States Bureau of Mines is collecting data on coal-mine explosions in the various States, and this circular is one of a series analyzing the causes and recommending methods for the prevention of similar occurrences.

ACKNOWLEDGMENTS

The data on this circular are based on records of the United States Bureau of Mines and the West Virginia Department of Mines. Unfortunately practically all of the early records were destroyed by fire in the State House at Charleston, W. Va.; the remaining records were made available to the authors by N. P. Rhinehart, chief of the Department of Mines, and his cooperation is gratefully acknowledged.

HISTORICAL RESUMÉ

The earliest available reference to coal in West Virginia is that made by John Peter Lally who in 1742 found "a great plenty of coals" near a river later called Coal River. In 1809, Nicholas Roosevelt found coal along the Ohio River and used it on the New Orleans, said to have been the first steamboat west of the Allegheny Mountains. In 1810, Conrad Cotts opened a mine near Wheeling and sold coal for domestic purposes; in 1812, a mine was opened on the Ohio River opposite Mason City and produced 1,200 bushels of coal that year. In 1840 the total West Virginia coal production was 298,691 tons; in 1863, the production had increased to 444,468 tons, and in 1883, to 2,335,833 tons. During this period apparently most of the coal was extracted from coal outcropping on the hillsides; little danger of gas ignition existed at that time, but explosions from blown-out shots occurred frequently. On February 22, 1883 the West Virginia legislature enacted legislation providing for a mine inspector to inspect the mines of that State, to prevent mine accidents, and to insure properly ventilated mines.

In a special report to the Governor on December 31, 1884 the Inspector of Mines reported:

> We have 5 shafts, in 4 of which there is more or less gas; and in 1 of our drift mines there was an explosion on the 27th day of March 1880, whereby 2 men were killed and a boy badly burned.

Table 1 lists 287 explosions in West Virginia coal mines. Several early explosions were listed in the annual reports of the West Virginia

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Department of Mines as "blown-out shots" or "powder explosions". The injuries usually were described; explosives accidents have been eliminated from these and other available data, and only those in which dust or gas were involved have been included in this paper as explosions.

NUMBER AND COST OF FATALITIES FROM COAL-MINE EXPLOSIONS IN WEST VIRGINIA

During the more than 50 years covered by the tabulation, 287 explosions have occurred, entailing the loss of 2,060 (approximately 41 each year) lives and injury of at least 383 persons. Judging from the limited number of explosions on which complete data are available, more than 2,631 persons escaped uninjured from mines or sections of mines in which explosions occurred.

Number of Fatalities

No fatalities were caused by mine explosions in 12 of the 50 years--1883, 1884, 1887, 1888, 1889, 1890, 1893, 1894, 1896, 1897, 1898, and 1913. No explosions occurred in 7 of these 12 years. The largest number of explosion fatalities (501) occurred in 1907.

Gas and dust explosion fatality rates from 1887-1933, inclusive, are given in table 2. During the first 8 years (1883-90) the fatality rates were 1.134 per million tons of coal mined and 0.358 per million man-hours worked. The man-hours of exposure for 1883-90 and 1891-1900 were calculated from the number of men employed, the average number of days worked, and the average length of shift worked in the following 10-year period (1901-10). The highest rate per million tons of coal mined was 2.119 in 1901-10, and the lowest rate was 0.429 in the decade ended 1930. The fatality rate in 1933 was 0.036 per million tons, the lowest since inspection of mines was instituted in the State. The exceptionally high rate in 1901-10 was caused largely by the death of 361 men in the Monongah explosion. The fatality rate on the exposure basis ranges from 0.974 per million man-hours in 1901-10 to 0.255 per million man-hours in 1891-1900. The fatality rate of 0.152 in 1931 was lower than the average for any preceding period and the rate of 0.068 per million man-hours in 1932 was much lower. The man-hours of exposure in 1933 are not available, but from all indications the 1933 rate will be the lowest recorded by the West Virginia Department of Mines.

The ratio of explosion fatalities to all coal-mine deaths indicates the effect of eliminating explosion hazards. The percentage ranges from 30.4 in 1901-10 to 10.8 in the period 1921-30. During the last 3 years the ratio has decreased annually; in 1931 the percentage was 6.0; in 1932 it was reduced substantially to 2.7 percent; and in 1933 it was reduced to 2.0 percent.

Case no.	Date	County	Type of opening.
11	1892 Nov. 21	Brooke	Drift, non-gassy
	1893	-	-
12	1894 Sept.19		Drift
13	Nov. 20	Brooke	do
14	Dec. 3	Fayette	Drift, gassy
15	1895 Jan. 1	do	do
16	May 5	Marion	Drift
	1896	-	-
17	1897 Dec. 15	Fayette	Drift, gassy
18	Dec. 20	Marshall	do
19	Dec. 21	do	do
20	1898 July 7	do	do
21	Aug. 22	Fayette	do
22	Oct. 10	Ohio	Shaft, gassy
23	Nov. 26	Fayette	Slope, gassy
24	1899 Mar. 18	McDowell	Shaft, gassy
25	Aug. 21	Fayette	Drift, gassy

2024

of u- n	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. Killed
	-	-	-	-	-	-	-	0	0
	-	-	-	-	-	-	-	0	0
	Open light	-	Improve ventilation, inspect for gas	0	1	-	-		
g	Blasting	Boys stayed in mine after shift	Blast only under supervision	0	4	-	-		
	Open light or blasting	"Smoke" or gas ignited after blasting	Test for gas after blasting	0	1	-	-		
ft	Open lights	Mine idle, no inspection for gas	Inspect for gas with flame safety lamp	3	0	0	-		
ate a-	Open light	Gas ignited at face of entry	Ventilate face of entries, test for gas	0	1	-	-	5	3
en; ng d	do	Ditch-diggers opened an old door	Use fan instead of steam; use self-closing doors	39	0	0	-		
g	do	Gas released by blasting, ignited by open light	Ventilate face, test for gas after blasting	0	2	-	-	2	39
	-	-	-	-	-	-	-	0	0
	Open light	-	-	0	2	-	-		
g	Blasting	-	Ventilate face of workings, test for gas after blasting	0	3	-	-	2	0
	-	-	-	-	-	-	-	0	0
	-	-	-	-	-	-	-	0	0
er d	Open light	Gas issuing from clay vein for one week	Ventilate place; frequent tests for gas	4	0	0	-	1	4

1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
rage o. em- ployed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
47	-	Dust	Local	-	-	Explosion of black blasting powder	Considerable dust; 25-lb. kegs of black blasting powder in mine	Restrict amount of explosives	3	10	-	-	1	3
-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
132	-	Gas	Local	-	-	-	-	Use small charges of explosives	-	1	-	-	1	0
35	-	Dust	do	-	Blasting off solid	Two blasts fired simultaneously	Shooting off the solid	Undercut coal, place holes properly	8	2	-	-		
122	-	Gas	do	Small body of gas	-	Unknown	Ignition of gas	-	2	0	-	-	2	10
113	-	do	do	-	-	do	do	-	0	1	-	-		
600	-	Dust	do	-	Blasting off solid	Blown-out shot	Black blasting powder ignited	Undercut coal, place holes properly	4	0	-	-	2	4
-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
194	-	Gas	Local	-	-	Unknown	Ignition of gas	-	0	1	-	-		
-	-	do	do	-	-	do	do	-	0	1	-	-		
-	-	do	do	-	-	do	do	-	0	4	-	-	3	0
25	-	do	do	-	-	do	do	-	0	1	-	-		
117	-	do	do	-	-	do	do	-	0	1	-	-		
73	-	do	do	-	-	do	do	-	0	2	-	-		
175	-	do	do	-	-	do	do	-	0	1	-	-	4	0
65	-	do	do	-	-	Probably open light	Keg of black blasting powder exploded	-	1	0	-	-		
130	-	do	do	-	-	Unknown	Ignition of gas	-	1	2	-	-		

TABLE 1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
				Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
26	Sept. 10	Marion	Drift, gassy	165	-	Gas	Local	-	-	Unknown	Mine dusty, ignition of gas	-	1	0	-	-		
27	Oct. 9	Ohio	Shaft, gassy	69	-	do	do	-	-	do	do	-	1	0	-	-	4	4
28	1900 Feb. 19	McDowell	Drift, gassy	90	-	do	do	-	-	do	do	-	1	0	-	-		
29	Mar. 6	Fayette	do	138	-	Gas and dust	Extensive	-	Door not closed tightly	Open light	Miners violated law; did not wait for section to be inspected	Inspect mine before men are allowed to enter	46	3	-	-		
30	May 16	do	do	96	-	Dust	Local	-	-	Unknown	Probably blasting	-	0	1	-	-		
31	May 17	Preston	Shaft, gassy	44	-	Gas	do	-	-	do	Ignition of gas	-	0	1	-	-		
32	May 21	Fayette	Slope, gassy	200	-	do	do	-	-	do	do	-	0	2	-	-		
33	July 18	Mercer	-	275	-	Dust	do	-	-	Blown-out shot	-	-	0	2	-	-		
34	Nov. 2	Barbour	Drift, non-gassy	146	-	Explosives fumes, dust	Extensive	-	Fan stopped	Explosives	May have been intentional	-	15	1	4	-		
35	Dec. 17	Harrison	Drift, gassy	66	-	Dust	Local	-	-	Blown-out shot	-	-	0	1	-	-	8	62
36	1901 Jan. 16	Mingo	do	191	-	Gas	do	-	-	Black blasting powder	-	-	0	1	-	-		
37	Jan. 17	do	do	191	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
38	Feb. 2	McDowell	Drift	116	-	do	do	-	-	Unknown	Probably blasting	-	0	3	-	-		
39	Mar. 6	Barbour	Drift, non-gassy	146	-	Gas	do	-	-	do	Ignition of gas	-	0	1	-	-		
40	Mar. 26	Mingo	Drift, gassy	191	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
41	Mar. 30	Harrison	do	50	-	do	do	-	-	do	-	-	0	1	-	-		
42	May 15	Marion	Shaft, gassy	56	-	do	Extensive	-	Compressed air line closed	Open shot	Two rib shots fired simultaneously	Provide split ventilation	10	5	-	-		

TABLE 1 - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
				Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. Killed
43	Sept. 16	Mercer	Drift	75	-	Dust	Local	-	-	Blown-through shot	-	-	0	1	-	-		
44	Oct. 14	Putnam	Slope	203	-	do	do	-	-	Blown-out shot	-	-	0	1	-	-		
45	Oct. 14	Preston	Drift	152	-	do	do	-	-	do	Some dust in front of shot hole	-	0	6	-	-		
46	Oct. 24	Marshall	Shaft, gassy	68	-	do	do	-	-	do	-	-	0	1	-	-	11	10
47	1902 Mar. 17	Marion	Shaft, gassy	16	-	Gas	Local	-	-	Unknown	Ignition of gas	-	0	4	-	-		
48	Mar. 19	do	Drift, gassy	234	-	do	do	-	-	do	do	-	0	1	-	-		
49	Mar. 25	Preston	Drift	71	-	Dust	do	-	-	Blown-out shot	-	-	0	2	-	-		
50	June 23	Tucker	do	370	-	do	do	-	-	Blasting	-	-	0	2	-	-		
51	Sept. 15	McDowell	Drift, gassy	160	-	Gas	Extensive	-	Auxiliary fan; idle Saturday night to Monday morning	Open light	Auxiliary fan; incomplete examination for gas	Install overcast and regulator; remove door from main heading; split air	17	-	11	-		
52	Sept. 22	Marion	Shaft, gassy	34	-	do	Local	-	Door left open	Blasting	-	-	6	4	-	-		
53	Oct. 20	Fayette	do	55	-	do	do	-	-	Unknown	Ignition of gas	-	0	1	-	-		
54	Nov. 5	Marion	Drift	55	-	Dust	do	-	-	do	-	-	0	1	-	-		
55	Dec. 3	Fayette	Drift, gassy	103	-	Gas	do	-	-	do	Ignition of gas	-	0	1	-	-		
56	Dec. 6	Harrison	Drift	51	-	Dust	do	-	-	Blown-out shot	-	-	0	5	-	-	10	23
57	1903 Jan. 18	Fayette	do	50	-	Explosives smoke	do	-	-	Unknown	Ignition of explosives fumes	-	0	1	-	-		
58	Feb. 3	Harrison	do	43	-	Dust	do	-	-	Blown-cut shot	-	-	0	1	-	-		
59	Mar. 9	Mineral	do	32	-	do	do	-	-	do	-	-	0	2	-	-		

f -	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. Killed
n- on	Open light	Brushing out gas with coat	Improve ventilation, course air to face	1	0	-	-		
	Blasting	Flame from blast ignited explosives	Store explosives in safe place	2	0	-	-		
	do	-	-	0	11	-	-		
	Blown-out shot	-	-	0	1	-	-		
	do	-	-	0	1	-	-		
	do	-	-	0	1	-	-		
	Open light	Men entered mine in spite of orders to wait until mine was examined	-	1	0	-	-		
	Keg of explosives	-	-	3	0	-	-		
	do	-	-	0	2	-	-		
	Open light	-	-	0	1	-	-	13	7
	Blown-out shot	-	-	0	1	-	-		
	do	-	-	0	3	-	-		
	do	-	-	0	1	-	-		
	Open light	Had not been examined by fire boss	-	2	2	-	-		
	Blown-out shot	-	-	0	1	-	-		
	do	-	-	0	1	-	-		
	do	-	-	0	1	-	-		
	do	-	-	0	1	-	-		
	do	-	-	0	1	-	-		
	Unknown	-	-	0	1	-	-		

Case no.	Date	County	Type of opening
80	July 11	McDowell	Drift, gassy
81	Dec. 2	Kanawha	Drift
82	Dec. 4	Fayette	Shaft
83	1905 Jan. 30	Marion	Drift
84	Feb. 24	Barbour	do
85	Feb. 26	McDowell	Shaft, gassy
86	Mar. 16	Fayette	Shaft
87	Mar. 17	Marshall	-
88	Mar. 18	Fayette	Drift, gassy
89	Mar. 19	do	do
90	Apr. 20	Kanawha	Drift, non-gassy
91	May 2	Harrison	-
92	July 5	McDowell	Drift, gassy
93	July 16	Fayette	Shaft

- Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

Men verage o. employed	In mine	Explosion Type	 Extent	 Limited by	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year No. of explosions	 No. killed
-	-	Gas	Local	-	-	Open light	-	-	0	1	-	-		
-	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
168	-	Gas	do	-	-	Open light	-	-	0	1	-	-	13	2
-	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
-	-	Gas	do	-	-	Unknown	-	-	0	1	-	-		
7	7	Gas and dust	800 ft.	Unlimited	Air carried dust	Open light and explosives	Open light ignited tool box containing explosives. Passed over danger sign.	Obey mining law	7	0	-	-		
-	-	Gas	Local	-	-	Unknown	Ignition of gas	-	0	4	-	-		
-	-	do	do	-	-	do	do	-	0	2	-	-		
-	13	Dust	Extensive	Unlimited	Dust caused by blasting	Explosives on track	Car apparently ran over explosive	Persons should not enter mine before it is examined	13	0	0	-		
-	11	Gas	do	-	Explosion interrupted ventilation	Open light	Rescuers wearing open lights	Rescue workers should be organized	11	0	0	-		
-	8	Dust	do	Unlimited	-	Black blasting powder	Opened keg with pick or spark from open light	Sprinkle dust; limit of 5 lbs. explosives per man	6	2	-	-		
-	1	Gas	Local	-	-	Open light	Miners entered idle unventilated workings	-	1	0	-	-		
-	11	Gas and explosives smoke	do	-	Fall of slate, improper ventilation	do	Blown-through shots. Kegs of black blasting powder	-	5	6	-	-		
89	2	Gas	do	-	-	do	Entered mine on Sunday	-	2	0	-	-		

Case no.	Date	County	Ty o ope i
109	June 23	Kanawha	Dr
110	July 7	McDowell	Dr ga
111	July 19	do	Sha ga
112	Sept. 30	Preston	Slo
113	Nov. 30	Fayette	-
114	Dec. 6	Mineral	Dr
115	Dec. 20	Tucker	d
116	1907 Jan. 1	Harrison	d
117	Jan. 26	Upshur	Dr ga
118	Jan. 29	Fayette	Sha ga
119	Feb. 4	Tucker	Dr ga
120	Feb. 14	Marion	d
121	Feb. 16	Logan	Dr
122	Feb. 25	Kanawha	d
123	May 1	Fayette	Sha ga
124	June 27	McDowell	-

ause of accumu- lation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area unin jured	Compensa- tion cost	Total for year: No. of explo- sions	Total for year: No. killed
npressed ir was hut off	Open light	50 feet ahead of air	Conduct air to face. Limit amount of explosive. Do not depend on compressed air for ventilation	1	2	-	-		
-	Unknown	Gas ignition	-	0	1	-	-		
-	do	Explosives fumes present	-	0	1	-	-		
o rapid lasting	Blasting	Explosives fumes	Men remain at safe distance	1	2	-	-		
-	do	do	-	0	1	-	-		
-	Unknown	Gas ignition	-	0	2	-	-		
or left pen	Blown-out shot	Keg of black blasting powder ignited	-	7	1	-	-	18	54
-	Blasting	Keg of black blasting powder ignited	Limit explosives issued to each man	22	0	0	-		
-	Blown-out shot	-	-	0	2	-	-		
-	do	Shooting off solid; dry dust	Wet dust, undercut coal	18	0	0	-		
-	do	Hole drilled on solid	-	3	2	-	-		
ll of oof	Open light	Dry dust; only one opening	Provide two openings	23	0	12	-		
ll in illar orkings	Blown-out shot	-	-	23	0	102	-		
-	do	-	-	0	3	-	-		
-	Open light	Entered mine before it had been examined; disobeyed orders	-	1	0	-	-		

1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

f en- ng	Men		Explosions			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
	Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
ift	45	-	Dust	Local	-	-	Blown-out shot	-	-	0	2	-	-		
ift, assy	145	-	Gas	do	Small body of gas; inert dust	Entries idle; falls of roof	Open light	Mine had not been examined	Examine for gas before men enter	4	0	-	-		
aft, assy	24	5	do	Extensive	Unlimited	No ventilation	do	Descending shaft that was being sunk	Ventilate shaft; examine for gas	4	1	0	-		
ope	47	-	do	Local	-	-	Unknown	Gas ignition	-	0	1	-	-		
	-	-	do	do	-	-	do	do	-	0	1	-	-		
ift	72	-	do	do	-	-	Blown-out shot	-	-	0	1	-	-		
	37	-	do	do	-	-	Unknown	Gas ignition	-	0	1	-	-	15	98
	94	-	Dust	do	-	-	Blown-out shot	-	-	0	2	-	-		
ift, assy	160	12	do	1 entry	Expansion	-	Open light	Careless handling of keg of explosives	-	12	0	-	-		
aft, assy	100	100	Gas and dust	Extensive	Unlimited	Sudden liberation of gas	do	Use of black blasting powder	Use of safety "powder"	85	0	20	-		
ift, assy	134	25	do	do	do	Power failed; fan stopped	do	Fire boss did not examine mine	Provide proper supervision; examine for gas	25	0	0	-		
	214	-	Dust	Local	-	-	Blown-out shot	-	-	0	3	-	-		
ift	28	-	do	do	-	-	do	-	-	2	2	-	-		
	26	-	do	do	-	-	do	-	-	0	1	-	-		
aft, ssy	137	-	Gas and dust	Extensive	Wet entry	-	Dynamite	Three shots on solid fired rapidly	Undercut or shear coal; use safety "powder"	16	0	-	-		
	25	-	Gas	-	-	-	Blown-out shot	Black blasting powder ignited	-	0	1	-	-		

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Case no.	Date	County	Type of open- ing
143	July 20	Fayette	Shaft gass
144	July 20	McDowell	Drift
145	Sept. 10	do	do
146	Dec. 20	do	Drift non- gass
147	1909 Jan. 12	do	do
148	Mar. 31	Fayette	Drift
149	Apr. 15	Marion	Shaft
150	June 24	McDowell	Slope
151	June 24	do	do
152	July 2	Raleigh	Drift
153	July 15	McDowell	do
154	Sept. 3	do	do
155	Sept. 13	do	do
156	Sept. 16	Fayette	do
157	Oct. 25	McDowell	–
158	Dec. 2	do	–
159	1910 Feb. 2	Mercer	Drift
160	Feb. 28	Nicholas	do
161	Mar. 23	Fayette	Shaft
162	Apr. 12	McDowell	Drift
163	Apr. 27	Kanawha	do

e of mu- ion	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. Killed
	Unknown	Gas ignition	–	0	1	–	–		
	Blown-out shot	–	–	0	2	–	–		
	Unknown	Gas ignition	–	0	1	–	–		
	do	do	–	0	1	–	–		
	do	do	–	0	1	–	–		
	do	do	–	0	4	–	–		
	Blown-out shot	–	–	0	2	–	–		
	do	–	–	0	2	–	–		
	Unknown	Gas ignition	–	0	1	–	–		
	Blown-out shot	–	–	0	1	–	–		
	Electric arc from runaway	Trip ran down slope. Kegs of explosives helped propagation	Wet dust; place fan to one side of drift. Use safety "powder", isolate the two mines	361	1	0	–		
	Blown-out shot	–	–	0	2	–	–	21	501
ing solid	do	Used dynamite as well as Nyalite	Undercut or shear coal; use safety "powder"	9	1	0	–		
	Unknown	Gas ignition	–	0	1	–	–		
	do	do	–	0	1	–	–		
	do	Smoke from blasting	–	1	0	–	–		
	do	Gas ignition	–	0	1	–	–		
	Open light	–	–	0	1	–	–		

1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
80	-	Gas	Local	-	-	Unknown	Gas ignition	-	0	2	-	-		
140	-	do	do	-	-	do	do	-	0	1	-	-		
140	-	do	do	-	-	do	do	-	0	2	-	-		
243	70	Dust	Extensive	-	Shooting off solid	Blown-out shot	Improperly placed and overcharged shots	Employ shot firers to blast when all others are out of mine. Use clay stemming, remove "bug dust"	50	2	18	-	10	60
243	66	do	do	-	do	do	do	do	67	1	-	-		
47	-	do	Local	Dust was damp	-	Open shot of dynamite	Excessive charge, no hole or stemming	Observe mining law	6	0	-	-		
147	-	Gas	do	-	-	Unknown	Gas ignition	-	3	0	-	-		
57	-	do	do	-	-	do	do	-	0	3	-	-		
55	15	Dust	do	-	-	Blown-out shot	-	-	1	6	-	-		
61	-	do	do	-	-	do	-	-	0	1	-	-		
218	-	do	do	-	-	do	-	-	1	0	-	-		
150	-	do	do	-	-	do	-	-	0	1	-	-		
112	-	do	do	-	-	Blown-out shot	-	-	0	1	-	-		
86	-	Gas	do	-	-	Unknown	Gas ignition	-	1	0	-	-		
-	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
-	-	Gas	do	-	-	Unknown	Gas ignition	-	0	5	-	-	12	79
300	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
80	-	do	do	-	-	do	-	-	0	1	-	-		
131	-	Gas	do	-	-	Unknown	Gas ignition	-	0	1	-	-		
145	-	Dust	do	-	-	Blown-out shot	-	-	0	1	-	-		
152	-	do	do	-	-	do	-	-	0	1	-	-		

Original from THE OHIO STATE UNIVERSITY

TA

Case no.		Date.	County	Type of open- ing
179		July 12	Marshall	Shaft, gass
180		Sept. 19	Mingo	Drift
181		Oct. 18	McDowell	Shaft gass
182		Dec. 12	Raleigh	do
183	1913	Jan. 18	Fayette	do
184	1914	Jan. 9	Marshall	do
185		Jan. 12	do	do
186		Apr. 28	Raleigh	do
187		Sept. 18	McDowell	do
188		Oct. 26	do	Slope
189		Oct. 28	Fayette	Drift
190		Oct. 28	do	do
191	1915	Feb. 6	do	Shaft gass
192		Feb. 23	McDowell	Drift
193		Mar. 2	Fayette	do

West Virginia coal mines, 1883 – 1933--Continued

se of cumu- tion	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. killed
–	Blown-out shot	–	–	0	5	–	–		
–	do	–	–	0	1	–	–		
–	Unknown	Gas ignition	–	0	1	–	–		
pped; arted hours fore plosion	Open light	Natural gas from nearby well	–	3	1	–	–		
io	do	do	–	0	1	–	–	10	3
–	Unknown	–	–	0	1	–	–		
shut wn 36 irs	Blown-out shot	Use of black blasting powder and Nyalite	Blast with permissible explosives	23	0	5	–		
lequate ntila- on	Open light	Disobeyed orders; no examination	Keep men out of mine until it is examined	1	3	–	–		
–	Blown-out shot	–	–	0	1	–	–		
r ven- lation	Electric light bulb	Restricted airway; no test for gas	Improve ventilation; examine for gas	6	3	–	–		
–	Open light	–	–	–	1	–	–		
tain moved	do	Lax examination for gas	–	18	4	133	–		
–	do	–	–	–	1	–	–	8	48
ms rned ead of r. In- equate ntila- on	do	Two mines connected by cross entries	Improve ventilation; use water; use safety lights	83	–	10			
–	Explosives	–	–	0	5	–	–		

Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

Men		Explosion											Total for year	
Average no. employed	In mine	Type	Extent	Limited by	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	No. of explosions	No. killed
75	10	Gas and dust	Limited	Inert dust	Fan stopped; mine idle 12 days	Open light	Mine reopened, section not examined	Run fan continuously; examine for gas before men enter; use closed lights	8	1	1	-		
242	-	Dust	-	-	-	Explosives	-	-	2	-	-	-		
0	0	Gas	4000 ft.	-	Mine idle 3 years; fan not running	Lightning, electric arc	-	-	0	0	0	0		
155	-	do	-	-	-	Open light (?)	-	-	0	1	-	-	6	93
81	-	do	-	-	-	do (?)	-	-	0	2	-	-	1	0
90	-	do	Local	Small body of gas	No line brattice	Open lights	-	-	0	4	-	-		
90	-	do	do	do	do	do	-	-	0	2	-	-		
-	246	Gas and dust	Extensive	Unlimited	-	Explosives	Overcharged shot, dry dust	Use safety lamps; separate two mines	183	0	63	$237,697		
146	-	Gas	Local	-	-	Unknown	Gas ignition	-	0	2	-	-		
81	-	do	do	-	-	do	do	-	0	1	-	-		
69	-	Dust, gas	do	-	-	Blown-out shot	-	-	0	1	-	-		
372	-	do	do	-	-	do	-	-	0	2	-	-	7	183
170	173	Gas and dust	do	Small body of gas	Open door	Open light	Gas detected, mine reported safe	Remove gas before men enter mine. Employ only responsible fire bosses	22	2	149	17,836		
316	-	Gas	do	-	-	Unknown	-	-	0	1	-	-		
375	168	Dust and gas	Extensive	-	Open door	Open light	Using dynamite	Systematize opening and closing of doors; rock dust; employ fire bosses	115	-	54	168,999		

Original from THE OHIO STATE UNIVERSITY

Case no.	Date	County	Type of opening
209	Oct. 19	Marion	Shaf gas
210	1917 Dec. 15	McDowell	Drif gas
211	1918 Dec. 15	do	Shaf gas
212	1919 Mar. 31	Logan	Drif
213	July 13	McDowell	Shaf gas
214	Aug. 6	Fayette	do
215	Oct. 9	McDowell	Drif gas
216	1920 Jan. 20	do	do
217	Feb. 26	do	do
218	Apr. 30	do	do
219	Oct. 29	Raleigh	Slope gas
220	1921 July 4	Logan	Drift gass
221	July 7	McDowell	Shaft gass

2024

se of umu- ion	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensa- tion cost	Total for year: No. of explo- sions	Total for year: No. killed
stopped re- ing	Open light	Men entered mine; disobeyed orders	Use closed lights, flame safety lamps	3	–	–	$6,886		
	Blown-out shot	–	–	1	–	–	–		
	Unknown	Gas ignition	–	0	1	–	–		
er idle	Torch	Men not supposed to be in shaft	–	2	1	–	–		
age n gas l	Open light	Mine foreman wore open light	Prohibit open lights during examinations	1	0	–	–		
re- sed	do	Gas had never been detected before	Use closed lights; make adequate examination	23	11	–	40,385	9	167
	Unknown	Gas ignition	–	0	1	–	–		
brat- e too g	Open light	Defective flame safety lamp. Open kegs of black blasting powder	Sprinkle, rock-dust, use closed lights	10	14	196	30,711		
	Unknown	Gas ignition	–	1	0	–	–		
	do	do	–	0	1	–	–		
	Blown-out shot	–	–	0	1	–	–		
left n	Electric arc or matches	–	Used closed lights; search men for matches. Improve ventilation	4	0	2	1,626		
	Unknown	Gas explosion	–	0	1	–	–		
	do	do	–	1	0	–	–		
of f	Open light	–	Used closed lights, inspect idle open workings	0	11	–	–		

- Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

-	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
	Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
t, sy	225	10	Gas and dust	Extensive	Unlimited	-	Unknown	-	-	10	0	0	$30,663	10	26
t, sy	89	20	do	do	Highly inert dust	Door open	Open light	Man disobeyed instructions; left door open	Use closed lights; use auxiliary curtain; make full fire-boss examination	18	0	2	-	1	18
t, sy	123	6	Gas	do	Expansion	Air short-circuited	Unknown	Gas ignition	Machine men should carry flame safety lamp. Examine for gas for night shift	4	0	2	8,992	1	4
t	-	-	-	-	-	-	Blown-out shot	-	-	1	-	-	-		
t, sy	90	-	Gas and dust	Extensive	Unlimited	Improper ventilation	Flame safety lamp	Mine foreman relighting lamp	Use magnetically-locked flame safety lamp	6	-	-	-		
	80	9	do	Local	Expansion	do	Unknown	Arc from locomotive cable	Rearrange ventilation; use permissible mining machine	7	-	2	17,397		
t, sy	106	-	Gas	-	-	-	do	Gas ignition	-	1	-	-	-	4	15
	106	-	do	Local	-	-	do	do	-	1	-	-	-		
	231	3	do	do	Small body of gas	Inadequate ventilation	Open lights	Passed over danger sign	Officials should observe danger signs	3	-	-	-		
	169	-	do	do	-	-	Unknown	Gas ignition	-	1	-	-	-		
e, sy	37	-	do	do	-	-	do	do	-	1	-	-	-	4	6
t, sy	-	-	do	do	-	-	do	do	-	1	-	-	-		
, y	140	-	do	do	-	-	do	do	-	2	-	-	-	2	3

Case no.	Date	County	Type of opening
237	Aug. 8	Marion	Sha ga
238	Nov. 20	Marshall	d
239	Dec. 12	McDowell	d
240	1925 Feb. 17	do	Slo
241	Mar. 17	Marion	Sha ga
242	Apr. 8	Logan	Slo
243	Oct. 3	McDowell	Sha
244	1926 Jan. 14	Marion	Sha ga
245	Mar. 8	Raleigh	d

West Virginia coal mines, 188[illegible] - [illegible]--Continued

ause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. Killed
-	Explosives	150 sticks explosives detonated. Mine idle	Do not overcharge shot holes	0	1	-	-		
-	Unknown	Gas ignition	-	1	-	-	-		
-	do	do	-	1	-	-	-		
-	do	do	-	1	-	-	-		
-	do	do	-	1	-	-	-		
-	do	do	-	1	-	-	-	6	5
-	Blown-out shot	Coal stemming used	-	0	5	-	-		
-	do	Mixed explosives	-	10	-	-	$22,319		
-	Unknown	Gas ignition	-	1	-	-	-		
-	do	do	-	1	-	-	-		
-	Open light	-	-	3	-	1	-		
tain wn r 25 utes	Electric arc	Nonpermissible electric drill	Use doors instead of curtains; use permissible equipment	27	0	37	68,611	6	42
enti- ted rk- gs	Open light	-	Seal abandoned workings, use closed lights, rock-dust	26	4	2	73,148		
e idle, n opped	do	Fan started, blew gas over open light	Use closed light; examine mine before men enter	1	2	-	-		
l of of	do	-	Use closed lights; rock-dust	119	0	0	397,760		

1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

-	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
	Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
ft, ssy	62	2	Gas	Local	-	Fan not running	Electric arc	Men entered in violation of instructions	-	2	0	0			
o	16	-	do	do	Out shaft to surface	Booster fan stopped	Smoking	-	-	3	1	-	-		
o	172	20	Gas and dust	Extensive	Standing water	Dust raised by fall	Electric arc	Spark from machine wire	Rock-dust; machine men should test for gas	2	0	18	-	6	153
pe	130	-	Gas	Local	Small body of gas ignited outby fan	Door left open	do	Locomotive cable burned	Examine for gas before mining machine enters	2	0	-	-		
ft, ssy	130	34	Gas and dust	Extensive	-	Interrupted ventilation	do	May have been high explosive, foot of shaft	Change ventilation, use doors in pairs, rock-dust	34	0	0	$99,053		
pe	106	3	Gas	Local	Ignition 150 outby face	Air short-circuited	Open light	Idle section	Seal or ventilate old workings	4	0	0	16,645		
ft	136	8	do	700 ft.	Wet dust	Curtain knocked down	Electric arc	Mining machine cables, "nipping" wire	Have positive control of air current	2	0	6		4	42
ft, ssy	260	47	Gas and dust	Limited	Low pressure	Open door, or fall	do	Poor wiring at face	Rock-dust, use permissible equipment	19	0	28	46,454		
o	397	68	do	Extensive	-	Interrupted ventilation	do	Machine man failed to test for gas	Make fire-boss examination before machine enters; rock-dust, seal abandoned areas	19	0	49	75,784		

se of rumu- tion	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. killed
: cked	Electric arc	Gas blown over trolley locomotive	Use permissible locomotive, extend rock-dusting	5	2	11	$21,266	3	43
:ain lled vn	do	Nonpermissible mining machine	Use permissible electrical equipment; rock-dust; employ fire boss at night	4	1	17	10,863		
-	Fire	Trolley locomotive ignited curtain	Use noncombustible material at doors	0	11	189			
short- rcuited t door	Electric arc	Nonpermissible storage-battery locomotive	Provide adequate ventilation; double doors; use permissible equipment	97	-	9	240,999		
l of of	do	Nonpermissible mining machine	Rock-dust, apply water on cutter bar	8	1	13	17,923		
tain rn down	Electric arc	Cable-reel locomotive	Double doors, rock-dust	3	3	16	7,697		
l of of	Open light	-	Closed light	2	-	18	-		
c	do	-	Closed lights, permissible equipment, rock-dust	2	-	18	-	7	116
l in llar	do	-	Closed lights, rock-dust, more air	8	0	112	25,116		
r ft en	do	-	Closed lights, rock-dust, water on cutter bar	3	0	77	10,452		

Case no.		Date	County	Typ of oper in
256		May 22	McDowell	Dri ga
257		June 20	Monongalia	d
258		Oct. 22	Raleigh	Dri no ga
259		Nov. 12	Logan	Dri ga
260		Nov. 30	McDowell	d
261	1929	Jan. 15	Marion	Sha ga
262		Jan. 26	Fayette	Dri no gas
263		Feb. 9	Braxton	Dri gas
264		Mar. 5	Monongalia	Slo no gas
265		June 9	Wyoming	Sha gas

1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Continued

e	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year	
n- g	Average no. employed	In mine	Type	Extent	Limited by									No. of explosions	No. killed
ft, ssy	170	40	Gas and dust	Local	Inert dust, expansion	Door left open	Electric arc	Open type mining machine	Permissible equipment, rock-dust	17	-	23	$49,219		
ɔ	115	22	do	600 ft.	Wet dust, expansion	Fall in pillar	Open light	-	Closed lights, rock-dust	7	6	9	18,401		
ft, n- ssy	200	22	Dust	Local	Expansion	-	Open shot	Using dynamite and fuse	Permissible explosives, confined in hole	6	0	15	13,565		
ft, ssy	-	7	Gas	do	-	-	Unknown	-	-	1	0	6	-		
ɔ	55	7	do	do	Standing water, expansion	Improper ventilation	Electric arc	Open type mining machine	Improve ventilation, use permissible equipment	6	0	1	17,001	7	48
ft, ssy	300	9	do	do	Weak ignition	Abandoned section	Open light	Man in abandoned section ignited gas that started fire	Seal abandoned workings, use closed lights	2	6	1	-		
ft, n- ssy	350	65	Gas and dust	do	Expansion	Fall of rock	do	Open shots fired	Closed lights, permissible explosives; confine explosive in holes	14	2	49	35,392		
ft, ssy	63	6	do	do	Damp dust	Door left open	do	Cut into a clay vein	Use closed lights, few doors; rock-dust	3	-	3	10,355		
pe, n- ssy	-	-	Gas	do	Small body of gas	Improper ventilation	do	Man lighted gas bubbles with lamp	Use closed lights; improve ventilation	1	-	-	-		
ft, ssy	200	60	Gas and dust	Limited	Rock-dust	Door open	Electric arc	Nonpermissible storage-battery locomotive	Use permissible locomotives; eliminate doors	4	-	56	17,097		

Case no.	Date	County	Type of opening
279	Dec. 28	McDowell	Shaft gass
280	1932 Feb. 2	Kanawha	Drift gass
281	Mar. 1	Raleigh	Drift non-gass
282	May 5	Kanawha	Slope non-gass
283	July 31	Logan	do
284	Nov. 5	Raleigh	Drift gass
285	Dec. 12	McDowell	Shaft gass
286	1933 Jan. 15	Monongalia	Slope gass
287	Aug. 22	Logan	do

ıse of ccumu- ation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	Total for year: No. of explosions	Total for year: No. killed
-	Unknown	-	-	2	-	-	-		
rly nti- ated	Open light	-	Ventilate to face, use closed lights, rock-dust, examine unsealed workings	2	-	12	$5,512	7	28
l of of	Electric arc or heat	Resistance of cable-reel locomotive ignited gas	Permissible locomotives, closed lights	8	4	1	13,405		
l ised ist	Electric arc	Arc from cable-reel locomotive	Permissible locomotives, rock-dust	12	0	2	27,101		
-	do	Defective cable on mining machine	Permissible equipment	1	1	-	-		
-	do	Arc from mining machine	do	0	0	-	-	4	21
r left en	do	Nonpermissible storage-battery locomotives	Permissible locomotives; install doors in pairs	8	0	50	18,992		
r left en one ur	do	Cable-reel locomotive	Use double doors; permissible locomotive	0	2	-	-		
; into d work- gs	do	Faulty maps	Test for gas while cutting, use permissible equipment	2	0	-	-		
r left en	do	Arc from gathering locomotives	Permissible locomotives, use double doors	1	1	148			
-	Unknown	-	-	2	0	148			
ls of of	Open light	Foreman carried flame safety lamp and open light	Rock-dust; use closed lights	5	6	235	26,961		
ng xil- ry fan	do	Nonpermissible pump on mining machine	Test for gas before cutting; use permissible equipment	3	0	-	-		

1. - Gas and dust explosions in West Virginia coal mines, 1883 - 1933--Concluded

Men		Explosion											Total for year	
Average no. employed	In mine	Type	Extent	Limited by	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Compensation cost	No. of explosions	No. killed
232	-	Gas	Local	Small body of gas	Blasting	Electric arc	Multiple-shot magneto used for blasting	Use permissible blasting devices	0	0	-	-	8	21
80	80	do	do	Wet area	No line brattice	do	Explosives may have detonated; open-type locomotive	Conduct air to face; rock-dust; use permissible locomotive	0	4	76	-		
-	-	do	do	Small body of gas	Fall in pillar	Open light	No fire-boss examination	Use closed lights, treat mine as gassy	0	3	-	-		
-	2	do	do	do	Improper ventilation	Electric arc	Arc, controller of locomotive	Use permissible locomotive; rock-dust	1	0	1	-		
85	4	Dust	Extensive	Expansion	-	Open shots	Firing from trolley wire	Use permissible blasting units; rock-dust	2	0	2	-		
45	-	Gas	Local	Wet dust and water	Curtain ineffective. Line brattice back too far	Electric arc	Nonpermissible locomotive	Keep line brattice up to face; rock-dust	3	1	-	-		
400	250	do	do	Rock-dust	Removing stopping	do	Trolley locomotive on intake air	Test for gas	1	1	248	-	6	7
75	2	Gas and dust	do	Wet dust, high ash in dust	Fan stopped, idle day	do	Officials turned on power before testing for gas	Run fan continuously	2	0	0	-		
78	50	do	do	Small body of gas ignited outby face	Fan stopped, power off	do	Cable-reel locomotive	Use permissible locomotives; not turn rooms off air course; rock-dust; use auxiliary fan drive	3	0	47	-	2	5
									2060	383	2661	$1,948,283	287	2060

TABLE 2. - Gas and dust explosion fatality rates in West Virginia coal mines, 1883 - 1933

Period	Fatalities per million tons	Fatality per million man-hours	Percent of explosion fatalities to total coal-mine deaths
1883-1890 (8 years)	1.134	[1] 0.358	20.9
1891-1900	.628	[1] .255	11.2
1901-10	2.119	.974	30.4
1911-20	.809	.419	14.2
1921-30	.429	.320	10.8
1931	.207	.152	6.0
1932	.082	.068	2.7
1933	.056	-	2.0
Average	.904	.459	15.6

[1] Estimated.

The efforts of the West Virginia Department of Mines, coal operators, safety engineers and mining institutes, in conjunction with individual reports, accident-prevention classes, and safety inspections of the United States Bureau of Mines have undoubtedly borne fruit in reducing the number and severity of coal-mine explosions. In 1933, the fatality rate per million tons of coal mines was 0.056 compared with 0.904 for the 50-year period; the fatality rate per million man-hours of exposure was 0.068 in 1932 compared with an average of 0.459; and the percentage of explosion fatalities to total coal-mine fatalities in 1933 was 2.0 compared with an average of 15.6 for the 50 years (1883-1932). This record is a clear indication of the results of explosion-prevention measures gradually adopted in West Virginia coal mines.

Cost of Fatalities

The cost of compensation paid for explosion fatalities in 37 cases amounted to $1,948,283, an average of $52,650 per explosion. The number of lives lost ranged from 2 to 183 and the total loss was 859 lives. The average cost of compensation was $2,268 per fatality. Assuming this to be an average cost the 2,060 explosion fatalities have caused a loss of $4,672,080 in compensation alone.

CAUSES OF COAL-MINE EXPLOSIONS IN WEST VIRGINIA

Most of the explosions were initiated by three major causes--explosives, open lights, and electricity; the assigned causes have been segregated in table 3 by major and minor causes by periods.

TABLE 3. - Alleged causes of coal-mine explosions in West Virginia, 1883-1933

Causes	1883 - 1890		1891 - 1900		1901 - 1910		1911 - 1920		1921 - 1930		1931 - 1933		Total	
	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed
Explosives	2	0	6	30	71	256	10	210	4	16	1	2	94	514
Blown-out shots	-	-	3	4	56	181	7	25	2	10	-	-	68	220
Blasting	2	0	-	-	7	31	2	2	-	-	-	-	11	33
Premature blast	-	-	2	18	4	9	-	-	-	-	-	-	6	27
Open shots	-	-	-	-	1	6	-	-	1	6	1	2	3	14
Multiple shots	-	-	1	8	1	16	-	-	-	-	-	-	2	24
Overcharged shots	-	-	-	-	-	-	1	183	1	0	-	-	2	183
Blown-through shot	-	-	-	-	1	0	-	-	-	-	-	-	1	0
Explosives on track	-	-	-	-	1	13	-	-	-	-	-	-	1	13
Open lights	7	42	3	51	24	215	21	313	15	197	3	8	73	826
Inadequate ventilation	-	-	-	-	3	28	3	198	12	191	1	3	19	420
Disobedience of orders of law	-	-	1	46	3	10	4	25	-	-	-	-	8	81
Lax gas examination	-	-	-	-	3	31	3	48	-	-	1	0	7	79
Mine idle; no examination	1	3	1	1	1	1	-	-	-	-	-	-	3	5
Men entered old workings	1	39	-	-	1	1	-	-	1	2	-	-	3	42
Gas from blasting	1	0	-	-	2	15	-	-	-	-	-	-	3	15
Officials or rescuers with open lights	-	-	-	-	1	11	1	1	-	-	1	5	3	17
Flame safety lamps	-	-	-	-	-	-	2	16	-	-	-	-	2	16
Explosives	-	-	-	-	2	97	-	-	-	-	-	-	2	97
Fan stopped, no examination	-	-	-	-	1	17	-	-	1	1	-	-	2	18
Torch	-	-	-	-	-	-	1	2	-	-	-	-	1	2
Gas from clay vein	-	-	1	4	-	-	-	-	-	-	-	-	1	4
Brushing out gas	-	-	-	-	1	1	-	-	-	-	-	-	1	1
Other causes	4	0	-	-	6	3	7	23	1	3	-	-	18	29

TABLE 3. - Alleged causes of coal-mine explosions in West Virginia, 1883-1933--Continued

Causes	1883 - 1890		1891 - 1900		1901 - 1910		1911 - 1920		1921 - 1930		1931 - 1933		Total	
	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed	No. of explosions	No. killed
Electricity	-	-	-	-	1	361	3	10	20	272	11	21	35	664
Arc, nonpermissible locomotive	-	-	-	-	-	-	-	-	8	163	8	17	16	180
Arc, nonpermissible mining machine	-	-	-	-	-	-	1	4	8	59	1	2	10	65
Spark from power wire	-	-	-	-	-	-	-	-	3	23	1	2	4	25
Arc, runaway trip	-	-	-	-	1	361	-	-	-	-	-	-	1	361
Spark, electric light on power line	-	-	-	-	-	-	1	6	-	-	-	-	1	6
Lightning	-	-	-	-	-	-	1	0	-	-	-	-	1	0
Arc, nonpermissible drill	-	-	-	-	-	-	-	-	1	27	-	-	1	27
Arc, nonpermissible blasting magneto	-	-	-	-	-	-	-	-	-	-	1	0	1	0
Miscellaneous	-	-	17	6	37	5	17	27	13	16	1	2	85	56
Unknown	-	-	17	6	37	3	17	27	11	13	1	2	83	53
Smoking	-	-	-	-	-	-	-	-	1	3	-	-	1	3
Fire	-	-	-	-	-	-	-	-	1	0	-	-	1	0
	9	42	26	87	133	837	51	560	52	501	16	33	287	2060

Explosives

Although causing the largest number of explosions (94), explosives ranked third among classified causes of fatalities, with 514 lives lost. Blown-out shots, caused by the use of black blasting powder and blasting "off the solid", were the chief factors in 68 explosions resulting in 220 fatalities. Several explosions of unknown cause probably were due to explosives or blasting. The largest number of deaths (181) and explosions (56) from blown-out shots occurred in the period 1901-10. Blasting (not otherwise classified), which caused 11 explosions and 33 deaths, ranked second among explosions from explosives; premature blasts were third, causing 6 explosions and 27 deaths; open shots or shots not confined in holes were fourth, causing 3 explosions in which 14 lives were lost; and multiple shots, overcharged shots, blown-through shots, and explosives run over by mine cars were other causes of this class of explosions. The peak of explosives-initiated explosions was reached in 1901-10, with 71 explosions and 256 deaths. In the following period 1911-20, only 10 explosions were caused by explosives, but the fatalities (220) were not proportionately decreased. In the 3 years from 1931 to 1933, only 1 explosion, resulting in 2 deaths, occurred from explosives.

Open Lights

Ignitions of gas and explosives are the two general direct causes of explosions initiated by open lights; however, to understand how open lights were responsible for the explosions, the contributing causes have been given. Inadequate ventilation, which allowed gas to accumulate, was responsible for 19 explosions in which 420 lives were lost. Men entering a mine or section of a mine before it was inspected, in disobedience to orders, caused 8 explosions and 31 deaths. Careless examination by fire bosses, ignoring gas known to be present, or failure to examine a mine or section caused 7 explosions and 79 fatalities. Other factors causing 1 to 3 explosions were: Men entering idle mine in which no examination had been made; gas liberated by blasting; officials wearing open lights while examining mine and rescue workers wearing open lights after an explosion; defective flame safety lamps; ignition of black blasting powder; men entering mine when fan had been stopped and no examination of the mine had been made; ignition of gas by a torch; ignition of gas issuing from clay vein; and brushing out gas.

Open lights caused 73 explosions resulting in 826 fatalities. The largest number of explosions (24) occurred in the 10-year period 1901-10 and the greatest number of fatalities (313) in the following 10-year period 1911-20.

Electricity

Sparks or arcs from electrical equipment caused 35 coal-mine explosions in which 664 lives were lost. The chief source of these explosions was nonpermissible locomotives, which caused 16 explosions and 180 deaths in 13 years. Nonpermissible mining machines ranked second with a record of 10

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explosions and 65 fatalities. Four explosions, causing 25 deaths, were initiated from sparks from trolley wires generally resulting from "nipping" or sliding the head hook of the cable along the trolley wire. An arc caused by a runaway trip on a slope ignited dust and caused the most disastrous explosion in the history of the mining industry of the United States, 361 men losing their lives. Lightning, an arc from a nonpermissible drill, and a spark from a nonpermissible drill, and a spark from a nonpermissible blasting magneto each caused 1 explosion; the only fatalities resulting (27) were in the explosion caused by the electric drill.

The largest number of electrically-initiated explosions (20 explosions, with 272 deaths) occurred in 1921-30. Explosions of electrical origin have increased steadily; 1 occurred in 1901-10, 3 in 1911-20, 20 in 1921-30, and 11 in the 3-year period 1931-33. In 1921-30 the average number killed was 13.6 per explosion, and in the following 3 years the average was practically 2 in each explosion.

Miscellaneous

Two causes of explosions listed under "miscellaneous" explosion causes--smoking and fires--might be appropriately listed under open lights. Each caused 1 explosion. Three deaths resulted from the explosion attributed to smoking, but no lives were lost in the explosion caused by a fire. Most of the 83 explosions, causes of which are unknown, were probably due to explosives and open lights.

PRINCIPAL CONTRIBUTING CAUSES OF EXPLOSIONS

Frequently several possible causes of explosions are found during investigations of disasters. Table 4 gives data as to secondary or possibly supplementing or suspected causes of explosions, the primary cause having been assigned to some other condition or practice. Among secondary causes of West Virginia coal-mine explosions listed in table 4 blasting ranks first, electricity second, and ventilation third.

Blasting

Ignition of black blasting powder and firing of overcharged shots were suspected of having contributed to 5 explosions each. Storing excessive quantities of explosives underground and using mixed explosives each were given as secondary causes in 4 explosions. Dust created by blasting "off the solid" undoubtedly helped propagate 3 explosions. Firing multiple shots was believed to have been largely responsible for 3 explosions. Firing open shots--that is, firing explosives that were unconfined in properly drilled holes--contributed to or caused 2 explosions. Firing shots by using the trolley wire as a source of power, ignition of explosives by flames from blasting, opening a keg of black blasting powder with a pick, firing dependent shots, employing combustible stemming, and blasting with dynamite and fuse were given as contributing causes of explosions.

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TABLE 4. - Principal contributing causes of explosions

Causes	Times reported
Blasting	33
Ignition, black blasting powder	5
Overcharged shots	5
Excessive quantities of explosives underground	4
Mixed explosives	4
Dust from shooting off solid	3
Multiple shots	3
Open shots	2
Firing from power wire	1
Flames from blast ignited explosives	1
Car ran over explosives	1
Opening keg of black blasting powder with pick	1
Dependent shot (hole on solid)	1
Combustible stemming	1
Dynamite and fuse	1
Electricity	18
Arc, nonpermissible locomotive	7
Arc, nonpermissible mining machine	5
Arc, trailing cable	4
Arc, "nipping" wire (sliding head hook on wire)	2
Ventilation	11
Gases given off by blasting	8
Mine or section idle; no examination	2
Restricted area in airway	1
Miscellaneous	6
Mine dusty	4
Two mines connected	2

Electricity

Arcs and sparks from electric equipment are a prolific source of explosions and in many cases are suspected of having had some part in the ignition of explosions of gas or dust; 18 of the contributory sources of explosions are attributed to electricity. Arcs from nonpermissible locomotives were suspected of contributing to 7 explosions; arcs from nonpermissible mining machines may have caused 5 explosions; an arc from a trailing cable was given as a secondary cause in 4 explosions; and "nipping" the wire or sliding the head hook of the trailing cable along the trolley wire may have caused 2 explosions.

Ventilation

According to reports of mine inspectors, ignitions of gaseous fumes given off by explosives and not carried away by the ventilating current were suspected of having caused 8 explosions; this now appears to be improbable; undoubtedly ignition of gas released by blasting or dust raised into suspension caused these explosions. Failure to ventilate an idle mine or an idle section and allowing men to enter without having the mine or section examined resulted in 2 explosions caused by open lights. Inadequate ventilation caused by restriction of the airway through falls of roof undoubtedly contributed to 1 explosion.

Miscellaneous

Accumulations of dust are thought to have contributed to the propagation of at least 4 explosions and the practice of having two adjoining mines connected allowed explosions to extend to adjacent mines during 2 explosions.

CAUSES AND PERCENTAGE OF EXPLOSIONS

The trend of explosion causes is shown in table 5. In the first 8 years considered (1883-90, inclusive) 22.2 percent of the explosions were caused by explosives and blasting, and 77.8 percent were attributed to open lights with no explosion charged to electricity. In the following period (1891-1900), explosives causes 23.1 percent of the explosions and open lights 11.5 percent; probably the remaining 65.4 percent of the explosions from unknown causes were due to explosives or open lights in about the same proportion, 2 to 1. In the 10 years 1901-10, explosives (53.4 percent) caused about 3 times as many explosions as open lights (18.0 percent); electricity enters for the first time as the initiator of explosions in the coal mines of West Virginia, being responsible for 1 explosion or 0.8 percent, while miscellaneous causes were responsible for 27.8 percent of the explosions. Following the high point of 53.4 percent attained in 1901-10, explosives as a cause of explosions in this State decreased in each succeeding period, causing 19.6 percent of the explosions in 1911-20, 7.7 percent in 1921-30, and 6.2 percent (only 1 explosion) in the 3 years 1931-33. Explosions caused by open lights reached the maximum in 1911-20, causing 41.1 percent of the explosions; in 1921-30 open lights caused 28.8 percent and in 1931-33, 18.8 percent. Explosions from electricity have increased steadily from none in the periods 1883-90 and 1891-1900 to 0.8 percent from 1901-10, 5.9 percent from 1911-20, 38.5 percent from 1921-30, and 68.8 percent in the 3 years 1931-33.

TABLE 5. - Causes and percentage of explosions by periods, 1883-1933

Cause	1883-1890 1/		1891-1900		1901-1910		1911-1920		1921-1930		1931-1933 2/		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Explosives	2	22.2	6	23.1	71	53.4	10	19.6	4	7.7	1	6.2	94	32.8
Open lights	7	77.8	3	11.5	24	18.0	21	41.1	15	28.8	3	18.8	73	25.4
Electricity	0	-	0	-	1	.8	3	5.9	20	38.5	11	68.8	35	12.2
Miscellaneous	0	-	17	65.4	37	27.8	17	33.4	13	25.0	1	6.2	85	29.6
Total	9	100	26	100	133	100	51	100	52	100	16	100	287	100

1/ 8 years.
2/ 3 years.

From 1883-1933 explosives caused 32.8 percent of all explosions, open lights 25.4 percent, and electricity 12.2 percent. The reduction in the percentage of explosions caused by explosives--from 53.4 percent in the period 1901-10 to 7.7 percent in 1921-20 and 6.2 percent in the 3 years 1931-33--has been due in large measure to the introduction of permissible explosives and the adoption of permissible blasting devices, used in a permissible manner, making blasting less hazardous. The first record of the use of "safety explosives" in West Virginia coal mines was contained in the annual report of the Department of Mines for 1908. In that year 425,432 kegs (25-pound kegs) of black blasting powder, 788,049 pounds of high explosive other than short-flame types, and 453,024 pounds of "safety powder" or short-flame explosives were used in West Virginia coal mines. The classes of explosives used in West Virginia coal mines from 1912-32, based on figures published by the United States Bureau of Mines, are recorded in table 6. In 1912 practically the same quantity of black blasting powder was used as in 1908, but the permissible explosives used had increased to nearly seven times the quantity used in 1908, the consumption in 1912 being 3,064,045 pounds. The use of permissible explosives has steadily increased, reaching a peak of more than 13 million pounds per year in 1926 and 1927. The decrease in explosions initiated by explosives has kept pace with the wider use of safer explosives and electrical blasting, together with more careful practices in the handling and use of all types of explosives in and around many of the West Virginia coal mines.

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TABLE 6. - Classes of explosives used in West Virginia coal mines

Year	Black blasting powder		High explosives other than permissibles, pounds	Permissible explosives, pounds
	Granular, kegs	Pellet, cases		
1912	456,582	-	553,320	3,064,045
1913	554,400	-	645,425	3,282,560
1914	566,692	-	510,725	3,212,449
1915	587,970	-	521,125	3,679,375
1916	718,220	-	570,625	4,055,445
1917	867,673	-	1,162,277	5,899,019
1918	614,841	-	971,795	5,902,357
1919	476,552	-	1,013,594	5,343,491
1920	662,491	-	1,631,477	8,382,184
1921	380,623	-	853,841	6,203,528
1922	523,203	-	957,048	8,214,968
1923	552,051	-	1,538,970	10,355,335
1924	497,109	-	1,498,611	9,032,907
1925	541,745	-	1,070,664	10,497,400
1926	557,851	-	1,089,567	13,068,975
1927	483,334	-	960,775	13,055,500
1928	197,873	215,489	749,330	10,350,810
1929	143,302	286,794	761,951	10,959,012
1930	94,927	260,590	703,443	9,086,556
1931	48,122	241,586	346,699	6,648,075
1932	26,834	196,523	295,720	5,005,740

The decrease in the percentage of explosions from open lights from 41.1 percent in the period 1911-20 to 28.8 percent in 1921-30 and to 18.8 percent for the 3 years 1931-33 has been due to a large extent to the increased use os permissible electric cap lamps, especially in mines in which explosive gas is liberated; there is now no reasonable excuse for an explosion or a fire caused by open lights in any mine as there are readily available and almost absolutely safe electric cap lamps for underground workers, giving them a more efficient as well as a much safer light than any available open light or lighting system for underground purposes.

The increase in explosions of electrical origin from nothing before 1901 to 33.5 percent in 1921-30 and to 68.8 percent in the 3 years 1931-33 reveals a decidedly serious condition which is to be expected because even with the introduction of open arcing or sparking types of equipment such as electric locomotives, particularly of the cable-reel types, electric mining machines, and electric drills haulage roads in many instances have been kept in return airways, ventilation has not been properly conducted to the working faces, and opportunities for ignition of gas by electric arcs and sparks have been numerous. The earnest efforts of some progressive mining companies to remove explosion sources or to protect against them will probably bring about a decrease in frequency of explosions of electrical origin, although with 11 explosions of electrical origin in the latest 3-year period (1931-33), there is no probability that the present 10-year period (1931-40) will have as good a record as to explosions of electrical origin in the coal mines of West Virginia as did the period 1921-30 when 20 such explosions are listed in table 5 as having occurred. Evidently West Virginia coal mines have before them a real problem in the prevention of explosions caused by electricity.

FATALITIES AND PRODUCTION

The production of coal is seasonal in West Virginia, just as it is in many if not most of the coal-producing States; while compiling data on explosions it was observed that in several instances explosions occurred when preparations were being made to reopen a mine that had been idle or that had been reopened shortly before the explosion occurred.

The United States Bureau of Mines has published the monthly production of coal since 1917, and the total monthly production for 1917-33, inclusive, has been assembled in table 7. The number of explosions by months for the two periods--1883-1933 and 1917-33--has also been recorded in table 7.

Table 7 shows that during the 17 years 1917-33 the coal mines of West Virginia had 78 explosions and that October was the month with maximum production of coal; but January, with 11 explosions, had the greatest number of explosions, although the production for January was practically equaled or actually exceeded by June, July, August, September, October, and November. September, with 3 explosions in the 17 years and with production but little below the maximum for any month, had the best record as to explosions in the West Virginia coal mines, although May also had but 3 explosions, tonnage being materially lower than that of September. Although January had the greatest number of explosions (11) in the past 17 years, November had 9, although with somewhat greater tonnage than January; March and April each with 9 explosions and considerably less tonnage than either January or November appear to be nearly as dangerous as January in occurrence of explosions in proportion to output.

TABLE 7. - Comparison of number of explosions with production by months

Month	Production 1917-33, tons	Number of explosions 1917-33	Number of explosions 1833-1933
January	150,631,000	11	31
February	139,645,000	4	21
March	139,993,000	9	34
April	138,221,000	9	22
May	145,700,000	3	19
June	150,867,000	6	20
July	150,233,000	5	25
August	162,032,000	6	12
September	160,062,000	3	22
October	171,598,000	7	27
November	151,233,000	9	26
December	139,981,000	6	28

TYPES OF MINES AND CLASSES OF EXPLOSIONS

The available State records do not classify mines as gassy or nongassy although most of the reports made by Bureau of Mines engineers give this information. It is assumed that if a gas explosion occurs in a mine it should be classified as gassy, although unquestionably many explosions of gas have occurred in mines classified as nongassy. Of the mines that have been classified, gas or gas and dust explosions occurred in 87 and dust explosions in 2 gassy mines; gas or gas and dust explosions occurred in 18 and dust explosions in 9 so-called nongassy mines. Of the 287 explosions 79 were primarily dust explosions and 208 were gas or gas and dust explosions.

The generally accepted classification of "gassy" or "nongassy" mines by the mining industry, especially since 1911, has been synonymous with "open-light" or "closed-light" mines. Many mines, known locally to liberate considerable amounts of methane, have been kept on the open-light basis for fear that changing to closed lights would result in orders to use "flameproof" electrical equipment only or to change trolley-locomotive installations from return aircourses to intakes. The folly of continuing the use of open lights in mines known to be gassy is shown by the record of gas ignitions by open lights; of the 73 open-light explosions 70 have been classified as gas or gas and dust, the general assumption being that a gas and dust explosion is the result of an ignition of gas which raises dust into suspension and the dust propagates the explosion. Hence it appears that many, if not most, so-called nongassy mines liberate some gas. Electric cap lamps became common about 1911, and safe and fairly efficient portable mine lamps

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were available at and from that time. Before 1911, 27 gas, 6 gas and dust, and 2 dust explosions were caused by open lights; from 1911-33, 23 gas, 14 gas and dust, and 1 dust explosions have been caused by open lights. These explosions in West Virginia coal mines as well as scores of others in other coal-producing States of the United States substantiate the assumption of engineers of the Bureau of Mines that all coal mines are potentially gassy and should be regarded as such, and it is very probable that until or unless this idea is accepted by all coal-mining people and placed in all State laws and regulations, there will continue to be explosions of gas or of gas and dust because precautions are not taken against occurrence of gas or its ignition if it should occur.

PRINCIPAL CAUSES OF GAS ACCUMULATION

Gas accumulation ordinarily is a question of inadequate ventilation which may be due to failure of the management to provide proper facilities and material for coursing the air, to carelessness or incompetence of officials, or to carelessness or neglect on the part of other employees. The principal causes of gas accumulation at the time of some of the explosions listed in table 1 have been correlated and recorded in table 8; it is admitted that in numerous instances the alleged causes or conditions as given by those who made reports on the explosions were by no means well-defined or stated.

Doors

Doors left open.- Leaving doors open has been the most prolific source of gas accumulation; at least 18 explosions were caused by this type of "failure". Generally mule drivers or locomotive crews prop doors open when entering a side entry or when crossing from one entry to a parallel one to haul a loaded car or to put an empty car in a working place. In one instance the locomotive crew, in a hurry to take an injured man to the shaft bottom, failed to shut a door in a gassy mine and the door remained open for an hour; when it was closed the ventilating current carried a gas accumulation over a locomotive, and an arc from the locomotive ignited the gas with a resultant explosion which was stopped by rock-dust or it might have resulted in one of the worst explosion disasters in the history of coal mining in the United States.

Wrecked door.- In another instance a wrecked door allowed gas to accumulate at the faces of several workings; when the door was replaced the gas was forced over a trolley locomotive operating on return air, and an arc from an open-type locomotive ignited the gas; the explosion caused a number of fatalities, although fortunately it occurred at night when only a relatively few men were in the section.

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TABLE 8. - Principal causes of gas and dust accumulations

Causes	Number of times reported
Gas accumulation	
Door left open	18
Fall of roof or coal	17
Fan stopped or shut off	13
Inadequate ventilation (not otherwise classified)	10
Blasting	7
Interrupted ventilation	6
Mine idle, no inspection for gas	4
Curtain damaged	4
Failure to use line brattice	3
Air short-circuited (not otherwise classified) .	3
Auxiliary fan stopped	3
Leakage from gas well	3
Stopping removed	2
Compressed-air line closed	2
Open, unventilated old workings	2
Gas feeder ignored	1
Curtain removed	1
Rooms turned ahead of air	1
Line brattice too long	1
Door wrecked	1
Fumes from fire	1
Cut into old workings	1
Line brattice too far from face	1
Dust accumulation	
Blasting off solid	5
Dust suspended by fall	2
Air carried dust	1
Dust caused by blasting	1

Check curtains.- Check curtains are in somewhat the same category as doors; 4 explosions resulted from damaged check curtains. In one instance the mining machine that cut coal between the day and night shifts tore down a curtain, and the motorman failed to notify the night motorman or mine foreman; a locomotive entered a place that was rising steeply and either the open arc light on the front of the locomotive or an arc from the wheel ignited a body of gas that had accumulated. Check curtains are so easily damaged by mining machines and locomotives and cars that where the air must be deflected doors of brattice cloth nailed to wooden frames are used to advantage to replace them.

Falls of Roof

In certain West Virginia coal beds relatively little gas issues from the roof, coal, or floor during ordinary mining operations but if the roof falls and breaks an overlying stratum of rock or bed of coal considerable bodies of gas are liberated. Ignition of gas released by falls of roof caused 17 explosions; 4 of the explosions occurred in one mine during a period of several years, and in each case the gas probably was ignited by an arc caused by a machineman "nipping" the wire or tramming his machine by sliding the end of the trailing cable along the machine wire.

Fans

Thirteen gas ignitions were caused by accumulation of gas when main fans were stopped, either through failure of power or because the mine was idle or the shift of men was out of the mine. (In some localities fans are operate only when the men are in the mine, a practice of doubtful utility in the dollars and cents savings supposedly effected; certainly it does not add to safety.) Frequently fans are stopped from Saturday afternoon until Monday morning. Sometimes the fans are not run in mines that are not working, but repairmen may enter; some of the 13 explosions from failure to keep fans operating were caused by men entering mines under these conditions or in violation of instructions issued by the supervising official.

Several explosions have occurred in mines in which booster fans were placed underground. Such installations are concrete evidence of inadequate ventilation; in at least some cases they contributed to accumulation of gas, and 3 explosions were definitely caused by ignitions of bodies of gas that had accumulated while auxiliary fans were stopped.

Inadequate Ventilation

Information regarding conditions surrounding 10 explosions was so meager that the cause of gas accumulation could only be classified as inadequate ventilation. From the content of the reports it is evident that air was coursed so that little if any ventilation reached the working places. Contributing causes undoubtedly were: Failure to install line brattice at working faces; excessive use of doors and use of leaky doors; use of brattice cloth or wooden brattices instead of airtight stoppings; insufficient volume of air; and narrow, crooked, choked aircourses.

Closely allied to inadequate ventilation is failure to use line brattices or to use them efficiently; at least 3 explosions resulted from ignition of gas which had accumulated at the face of workings due to failure to conduct the air current to the face by means of line brattices. The removal of stoppings allowed gas to accumulate and resulted in 2 explosions; this is purely a case of carelessness or incompetency. One explosion resulted from the use of line brattice that was too long. Many factors enter into air loss in line brattices; the air loss occurs primarily at the break-through end and at the top and bottom of ineffectively installed brattices. Another common fault with line brattices is that they terminate too far from the face; such a condition contributed in causing 1 explosion. Interrupted ventilation, not otherwise classified, caused 6 explosions.

Blasting

Gas is often released by blasting. Frequently gas issues from clay veins, and when a clay vein is exposed by blasting a gas feeder or a sudden liberation of gas occurs. Gas released by blasting was directly responsible for 7 explosions. At least 2 of these, occurring during the earlier periods reported, were attributed to ignition of explosives fumes; and while this may be possible, it appears unlikely, especially as other more probable causes were present at the time these explosions occurred.

Mine Idle

Men were allowed to enter at least 4 idle mines without a previous examination for gas; gas had accumulated in each instance, and open lights worn by the men ignited the gas. A somewhat similar condition existed when 2 explosions occurred in open, unventilated, unexamined workings because adequate precautions had not been taken to prevent entrance by men.

Other Causes

Other causes of gas accumulations were: Air short-circuited, not otherwise classified, causing 3 explosions; compressed-air line closed, resulting in 2 explosions; leakage of gas from gas wells passing through the coal bed, causing 3 explosions; a gas feeder, known to exist, was ignored and an explosion resulted; rooms turned ahead of ventilation allowed gas to accumulate and an explosion followed; a nonpermissible mining machine ignited gas released when the machine cut into old workings; fumes from a fire (in a region which evidently also liberated methane) were ignited by the fire.

PRINCIPAL CAUSES OF DUST ACCUMULATION

Cognizance of dust participation was rarely taken into consideration by the early investigators of the explosions listed in table 1. In 9 cases reference was made to dust accumulation. The surrounding circumstances in a number of other instances clearly indicate that dust entered into the explosion, and such explosions have been listed as dust explosions in table 1.

Blasting

In the period before permissible explosives were used extensively in West Virginia coal mines, the hazard of dust caused by blasting "off the solid" was recognized, and propagation of 5 explosions was credited to dust formed by this method of blasting. Another explosion was caused through the ignition and propagation of dust formed by blasting.

Dust Raised by Falls

Two explosions were attributed to the ignition by an electric arc of dust raised into suspension by a fall of roof. Still another explosion was caused by the ignition of dust carried by the air current; presumably fine dust raised by mining operations or mine haulage settled on timbers, roof, and ribs and when this dust was raised into suspension by an ignition of black blasting powder the dust propagated the flame.

LIMITING PROPAGATION OF EXPLOSIONS

Two widely known methods of arresting or limiting propagation of explosions have been used to a limited extent in West Virginia coal mines; they are watering and rock-dusting. The value of explosion-prevention methods has been so widely known that when an explosion failed to propagate throughout a mine, naturally wet conditions or high content of inert matter in the mine dust were studied and, where conditions justified, the conclusions were drawn that standing water, high content of incombustible material in the dust, or rock-dust was indicated to have been responsible for stopping the explosions. The explosions stopped by these conditions have been tabulated in table 9, to show the number of men in the mine at the time of explosion, the number killed, injured, and escaped uninjured from the affected mine area and the cause and type of explosion.

Standing water, wet dust, or wet areas were credited with arresting the flame of the explosion in 25 cases. More than 1,425 men were in the mines at the time of these explosions--the number in the mine and the number of men who escaped uninjured were not given for 3 explosions--and of this number 286 were killed, 55 injured, and 1,110 escaped uninjured. By eliminating the number killed and injured in the 3 explosions for which complete data were not available it is shown that 18.3 percent of the men in the mine were killed, 3.9 percent were injured, and 77.8 percent escaped uninjured.

High incombustible content of the mine dust was attributed as the cause for arresting 8 explosions. The explosion in case 254 was also credited with having been partly stopped by water or wet dust. More than 354 men were in the mines at the time of these explosions; 81 were killed, 1 was injured, and 276 escaped uninjured. If case 110, data for which are incomplete, is omitted the fatalities constitute 21.8 percent of the men exposed to the explosions, injuries constitute 0.3 percent, and those saved form 78 percent of the men in the mines.

Rock-dusting was not adopted to any considerable extent in West Virginia until after 1924; however, since November 15, 1926, 8 explosions have been stopped by rock dust, although in 1 explosion, case 246, wet entries were credited with helping to stop propagation of the flame. The fatalities in these 8 explosions constitute only 3.6 percent of the men exposed to the explo sions, the men injured constitute 0.9 percent of those in the mines at the tim of the explosions, and 95.5 percent of the men underground escaped uninjured.

TABLE 9. - Alleged causes of stopping explosions

Case	Men in mine	Killed	Injured	Escaped uninjured	Ignition by	Type of explosion
Stopped by standing water or wet area						
101	22	22	0	0	Blasting	Gas and dust
105	35	23	0	12	Blown-out shot	do
106	125	23	0	102	do	Dust
123	-	16	0	-	Dynamite	Gas and dust
148	-	6	0	-	Open shot	Dust
177	93	83	0	10	Open light	Gas and dust
199	200	23	11	166	do	Gas
201	220	10	14	196	do	Gas and dust
205	6	4	0	2	Electric arc	Gas
208	250	0	11	239	Open light	do
233	64	27	0	37	Electric arc	Gas and dust
235	3	1	2	0	Open light	Gas
239	20	2	0	18	Electric arc	Gas and dust
243	8	2	0	6	Electric arc	Gas
246	18	5	2	11	do	Gas and dust
247	22	4	1	7	do	do
251	22	3	3	16	do	Gas
254	120	8	0	112	Open light	Gas and dust
255	80	3	0	77	do	do
257	22	7	6	9	do	do
260	7	6	0	1	Electric arc	Gas
263	6	3	0	3	Open light	Gas and dust
280	80	0	4	76	Electric arc	Gas
284	-	3	1	-	do	do
286	2	2	0	0	do	Gas and dust
	1425	286	55	1110		
Stopped by incombustible dust						
101	22	22	0	0	Blasting	Gas and dust
110	-	4	0	-	Open light	Gas
179	10	8	1	1	do	Gas and dust.
210	20	18	0	2	do	do
253	140	2	0	138	do	do
254	120	8	0	112	do	do
256	40	17	0	23	Electric arc	do
286	2	2	0	0	do	do
	354	81	1	276		
Stopped by rock dust						
246	18	5	2	11	Electric arc	Gas and dust
265	60	4	0	56	do	do
270	2	1	1	0	do	Gas
271	20	0	0	20	do	do
272	58	8	0	50	do	Gas and dust
273	-	0	2	-	do	Gas
275	150	1	1	148	do	do
285	250	1	1	248	do	do
	558	20	7	533		

The data in table 9 indicate that if explosions occur in mines that are well rock-dusted a large majority of the men can be saved. In about 8 years approximately 533 lives have been saved in mines using rock-dust with fatalities of only 3.6 percent of the men exposed; where water and high-ash dusts stopped propagation of the explosions the fatality rates averaged 18.3 and 21.7 percent, respectively, which, while not as good as the record made by rock-dusting, is far better than the 100 percent which might have occurred and which has been known to occur in dry dusty mines with little or incombustible dust present. Moreover, where rock-dusting is maintained adequate protection is assured against the dust hazard but rock-dust cannot be expected to stop a purely gas explosion. From the 41 explosions in West Virginia coal mines for which complete data are available on the number in the mines, the number killed, injured, and escaped uninjured, it has been determined that 35.3 percent of those exposed to the explosions were killed, 2.4 percent were injured, and 62.3 percent escaped uninjured; these figures include the 41 explosions in table 9. The data on the 41 mine explosions listed in table 9 indicate that the 8 mines in West Virginia in which rock-dusting is known to have stopped the propagation of explosions had a much lower percentage of injuries or fatalities to those present and much higher percentage of those who escaped unharmed than the other mines.

At the inquest following one explosion a contractor with 32 years of mining experience ranging from trapper boy to mine foreman stated that he and 4 men who were with him undoubtedly were saved by effective rock-dusting. He stated in part -

> There is not anything in God's world to beat rock-dust, properly applied, in stopping a mine explosion. I hold my life to rock-dust; I wouldn't be here if it was not for rock-dust, and I wouldn't work or go in a gaseous mine if it was not rock-dusted. There is no doubt in my mind or to anyone familiar with the circumstances that rock-dusting saved the entire mine and the lives of everyone in it at the time of the explosion. We saw no black dust and almost had to feel our way from 1st east to the main west (1300 feet). There was a white cloud of dust on the main north west that filled our nostrils and ears and eyes, but it was a life-saving cloud.

COAL-DUST- AND GAS-EXPLOSION FACTORS

The average mining man who is not thoroughly familiar with the research in coal-dust and gas explosions conducted by the United States Bureau of Mines at its Experimental mine is perplexed when some explosions are localized for no apparent reason when conditions appear favorable for a widespread explosion, whereas under some apparently similar conditions an explosion is extensive. A brief description of explosion factors may lead to a better understanding of coal-mine explosions.

Coal-Dust-Explosion Factors

An explosion of coal dust may be considered as a rapid and progressive burning of the dust particles, during which time air and gas waves are set up and pressure is developed. To have a coal-dust explosion there must be a medium for raising the dust into a cloud sufficiently dense that a source of ignition will explode it.

The explosibility of a coal-dust cloud is influenced by a number of factors. Size of the dust is important. Tests at the Experimental mine indicate that it is difficult to explode dust which will not pass through a 20-mesh sieve, and that a dust cloud, to be readily ignitible, must contain finer dust and the cloud must be very dense. Under some conditions 15 to 25 percent of mine dusts passes through a 200-mesh screen, hence as far as size is concerned can be ignited. The coarser dust does not enter into the starting of an explosion to as great extent as the finer dust. Pulverized dust, classified as 85 percent through 200-mesh or finer, is likely to be considerably more explosive than 20 percent through 200-mesh dust, because the finer the dust the greater the surface exposed and the more rapid the oxidation or burning. Moreover, the finer dust is lighter than the coarser dust, therefore it is more easily thrown into a dense cloud and also remains in suspension for a longer time period.

Composition of the dust is an important explosion factor. The chief constituent of the coal that enters predominantly into its explosibility is the volatile matter. Apparently the inherent moisture, and possibly the inherent ash also, affect explosibility only to a limited extent. The explosibility of coals is expressed best as a ratio of the volatile matter to the total combustible matter (the fixed carbon plus the volatile matter). Other factors being equal, the higher this ratio the more explosive the coal dust, although in the high-volatile coals the increase in the ratio does not have as marked an effect as in the low-volatile coals. Explosibility of 20 percent through 200-mesh dust increases rapidly between ratios 0.14 to 0.25, remains practically constant between 0.25 and 0.40, and then increases slowly. Pulverized dust increases rapidly in explosibility between ratios 0.12 to 0.20 and then increases slowly. Explosibility may be measured by the amount of incombustible matter that must be added to prevent propagation of flame through the mixture of coal dust and incombustible matter.

The composition of the coal bed and consequently the ratio of volatile matter to total combustible may vary from place to place in the same mine as well as in the same locality; in fact it may vary at numerous horizons from roof to floor in the same coal face. An average has been taken for the various coal beds of West Virginia in which the explosions listed in table 1 occurred. The beds have been arranged in table 10 according to the number of explosions in each coal bed. Of the first 7 coal beds listed in table 10, those in which the greater number of explosions occurred, are in general the more highly explosive as indicated by the amount of incombustible matter required to prevent propagation of flame by the coal dust; the exception is the Beckley bed, in which 27 explosions occurred compared with 15 in the Upper Freeport.

TABLE 10. - Explosions and explosion fatalities by coal beds

Coal bed	No-fatality explosions	Fatality explo-sions	Total number explo-sions	Total number explo-sion fatal-ities	Ratio of volatile matter to total com-bustible of coal	Incombustibl required to prevent prop-agation of explosion, percent
Pittsburgh	32	33	65	739	0.400	61
Pocahontas No. 3	20	27	47	373	.243	58
Sewell	19	11	30	169	.273	62
Beckley (War Creek)	6	21	27	331	.200	49
Upper Freeport	12	3	15	87	.262	60
Pocahontas No. 4	2	10	12	22	.164	39
Fire Creek	6	5	11	189	.221	52
Eagle	4	7	11	54	.373	61
No. 2 gas	8	2	10	7	.385	61
Lower Kittanning	7	3	10	4	.275	61
Sewickley	0	7	7	22	.440	64
Island Creek	1	3	4	3	.381	61
Redstone	0	4	4	40	.413	62
Welch	2	1	3	1	.413	62
Thacker	1	1	2	3	.377	61
Chilton	0	1	1	1	.460	67
Coalburg	1	0	1	0	.398	61
Winifrede	0	1	1	2	.399	61

EXPLOSION-PREVENTION METHODS

Explosions can be prevented or localized if sources of gas and dust are eliminated, if sources of ignition are removed, and if defensive measures are adopted to stop an explosion when the above precautions are not observed or fail.

Use of Water

One of the earliest methods adopted to prevent coal-dust propagation of explosions was the use of water. Watering systems have failed to prevent propagation of explosions, even in mines where the system was supposed to be well-maintained. The main effect of water, in so far as its use in the prevention of coal-mine explosions is concerned, is to prevent coal dust from getting into the air to form a cloud; to do this dust from the Pittsburgh coal bed must contain about 25 percent moisture or enough water so that when the wetted dust is squeezed in the hands a well-compacted ball is formed. If this wetted dust is raised into the air it will propagate an explosion, and it is possible for an explosion of gas at its most explosive point to raise into the air wet dust, which can then propagate flame. Dust is difficult to wet, and explosions are said to have passed over pools of water on which coal dust was floating. If a pool of water is standing at the foot of a sloping section of an entry or narrow passageway, the pioneering wave may raise the water into a dense spray ahead of the explosion and it may quench the flame; this condition may have stopped some of the West Virginia explosions. The use of water on cutterbars of mining machines, on tops of loaded cars before they are hauled from the working place and from the inside sidetrack, on empty cars before they are hauled back into the mine workings, and on the coal face and coal pile before blasting, helps to prevent the dry coal dust from being thrown into the air to settle on surrounding roof, ribs, timbers, gob, and floor later; these uses of wetting practices minimize the coal-dust explosion hazard, not only at working places but also to some extent throughout the entire mine workings.

Rock-Dusting

Rock-dusting of all open accessible parts of the mine as far as the last open crosscut or to within at least 50 feet of the working face has been found an effective means of preventing dust ignitions and of localizing or preventing the extension of explosions. Rock-dust barriers, properly constructed and maintained, and strategically located to isolate the various sections of the mine, form a secondary protection, in the event that rock-dusting has not been maintained. The fact that at least 8 explosions were checked by rock-dust since November 15, 1926, in West Virginia coal mines and that 96.4 percent of the men exposed to these explosions were thought to have been saved by rock-dust, clearly indicates the efficacy of this explosion-prevention method.

Other Methods

Coal-dust accumulations may be reduced by watering, as outlined above, by using only tightly constructed cars, by prohibiting loading cars excessively above the top of the car, by cleaning tracks periodically, by using care in blasting operations, and probably by other means.

Gas accumulations may be prevented by providing an adequate volume of air and by properly splitting and coursing the air so that idle workings are adequately ventilated and every working face is swept by a current of air with a velocity strong enough to remove and make nonexplosive any explosive gas that may be liberated.

The elimination of sources of ignition is a relatively simple problem. Open lights of all kinds should be prohibited underground in any and every coal mine in West Virginia; permissible electric cap lamps are available and give stronger and more uniform light than can be obtained with open lights and with much greater safety not only as to fires and explosives but also as to other types of accidents. Permissible explosives and blasting devices, if used in a permissible manner, will prevent explosions from explosives and blasting, and if blasting is carefully planned and supervised the production o much fine coal and coal dust can be avoided. Permissible storage-battery loco motives, if maintained in a permissible condition, may be used to haul coal effectively and safely. Permissible electrical equipment is available for essentially all classes of mine work and its use decreases or eliminates the probability of explosions of electrical origin, if adequate care is taken to maintain it in safe condition; however, the so-called "flame-proof" or "explosion-tested" equipment generally fails to give adequate protection, and several explosions in West Virginia have resulted from equipment of this type. Even if the motor compartments are flameproof, equipment that uses a trolley pole or locomotives using cables provide a source of ignition as evidenced by West Virginia explosions caused by this type of equipment.

RECOMMENDATIONS

Methods for preventing mine explosions have been developed as coal production has increased during the past 51 years. In the early years of mine inspection in West Virginia the chief means of combating the explosion hazard was to recommend better ventilation. The first recommendation made by the first inspector of mines of West Virginia was that a law be enacted to require mine operators to provide a means of supplying at lease 100 cubic feet of pure air per minute for each man underground. The recommendations made following the various explosions have been assembled in table 11 and tabulated under si major headings.

TABLE 11. - Recommendations for preventing explosions

Recommendation	Times made
Ventilation	55
Use doors in pairs	10
Improve ventilation	9
Conduct more air to face of workings	6
Seal abandoned workings	4
Eliminate or use few doors	4
Split the air current	4
Control air current positively	2
Run fan continuously	2
Provide auxiliary fan on surface	2
Prohibit auxiliary fans underground	1
Build overcasts	1
Install a regulator	1
Prohibit compressed-air ventilation	1
Ventilate shafts, during sinking operations	1
Offset fan from line of airway	1
Use line brattices	1
Remove gas before shift of men enters mine	1
Control opening and closing of doors	1
Use auxiliary curtain at door	1
Do not use curtain instead of door	1
Make doors of fire-resistant material	1

TABLE 11. - Recommendations for preventing explosions - Continued

Recommendation	Times made
Administration and supervision	43
Fire-boss examination before each shift of men enters mine	17
Test for gas by fire boss or machineman before mining machine enters a place	6
Isolate connecting mines	3
Inspect nonworking sections	2
Officials to obey danger signs	2
Make proper inspections	1
Provide effective supervision	1
Fence off old workings	1
Provide two escapeways	1
Undercut or shear coal	1
Use derail at top of incline or slope	1
Remove machine cuttings from mine	1
Load out dust	1
Employ competent fire bosses	1
Search employees for matches	1
Treat a gassy mine as gassy	1
Fire bosses not to use locomotives while making examinations	1
Haulage to be on intake air	1
Lighting	35
Use permissible electric lamps	30
Use permissible, magnetically locked, flame safety lamps	3
Do not use open lights while making examinations	1
Prohibit mixed lights	1
Dust control	34
Rock dust	These recommendations are generally made concurrently
Apply water to cutter bars of mining machines	
Wet tops of loaded cars; wet empty cars	
Wet face region; sprinkle road beds	
Electricity	26
Use permissible electrical equipment	9
Use permissible mining machines	6
Use permissible locomotives	3
Examine trailing cables periodically	3
Place electric wiring and open-type equipment on pure intake air	3
Install face wiring properly	1

TABLE 11. - Recommendations for preventing explosions--Continued

Recommendations	Times made
Blasting and explosives	18
Use permissible explosives and blasting devices	9
Confine explosives in holes; prohibit open shots	2
Fire blasting devices in permissible manner	1
Limit explosives to 1 day's supply	1
Remain at safe distance during blasting	1
Prohibit shooting off the solid	1
Employ shot firers	1
Use clay (incombustible) stemming	1
Do not overcharge shot holes	1

Ventilation

The greatest number of recommendations (55) deal with ventilation. The greatest need appears to be the erection of doors in pairs, spaced so that a trip of cars may be contained between the doors and two doors having the same effect upon the air current will not be open at the same time. Improvement of ventilation, not otherwise specified, was recommended nine times. This probably correlates with the next recommendation, that more air should be conducted to the face of workings. It is difficult to ventilate idle workings, and the power cost entailed in attempting to do so would more than pay for erecting airtight seals, as suggested in the next recommendation. The safest system of ventilation is to split the air to allow impure air from a panel or set of rooms to be conducted to the main return airway; however, splitting can be overdone. The loss of air that should be conducted to the face of workings can be greatly reduced by decreasing the number of doors to a minimum and utilizing tight, well-constructed overcasts or undercasts to conduct air past other aircourses. The same trend of thought is expressed in the next recommendation--that the air current be positively controlled; running fans continuously is of vital importance in preventing gas accumulations and it is significant that at least 16 explosions were caused in West Virginia by stopping of fans. To insure continuous operation of fans an auxiliary fan and auxiliary source of power should be provided. Portable auxiliary fans should be prohibited underground; their use is an acknowledgment that the quantity of air is inadequate or that the air current is inadequately coursed. Some of the recommendations that were made only once are: Regulators should be installed to control the quantity of air on each split; use of compressed air as a means of ventilation should be prohibited; shafts should be ventilated while they are being sunk; fans should be offset at least 30 feet from the fan duct or entry to prevent their damage by an explosion; line brattices should be used to conduct air to gassy working faces; if gas is detected it should be removed before the shift of men is allowed to enter the mine. The opening and closing of doors should be positively controlled, and the use of latches to hold doors open should be prohibited; if it is impossible to eliminate doors or to install them in pairs, an auxiliary curtain should be hung to reduce to a minimum the chances for short-circuiting the air; however, curtains should not be used instead of doors, except in emergencies; doors should be constructed of fire-resistant material.

Administration and Supervision

The management evidently was at fault in at least 43 explosions. Examinations of mine by fire bosses before entrance of each shift of men was recommended 17 times; moreover, it was recommended 6 times that a fire boss or machineman test for gas in a place before the (electric) mining machine is taken into the place to be cut. Explosions were transmitted to adjoining connected mines in 3 instances and the recommendation that mines be isolated from adjoining mines is based on these cases. Failure to inspect idle workings adjacent to live workings caused at least 2 explosions; all open workings adjacent to live workings should be examined daily. Danger signs should be observed by officials as well as by other employees; failure by officials to do this caused at least 2 explosions. Some of the less frequently made recommendations are: proper inspections should be made by competent fire bosses; effective supervision should be provided; old workings should be fenced; at least two ways of escape should be provided; all coal should be undercut, centercut, topcut, or sheared; derails should be provided at the top of inclines or slopes; machine cuttings should be removed from the mine; excessive accumulations of dust should be loaded out; competent fire bosses should be employed; employees should be searched for matches; mines that give off gas should be operated as gassy mines; fire bosses and other officials should not use locomotives while making mine examinations; haulage should be on intake air.

Lighting

The elimination of open lights and the use of "safety" or permissible lights were recommended 35 times. The largest number of recommendations (30) was for the use of permissible electric cap lamps. The use of permissible flame safety lamps was recommended three times. The prohibition of the use of open lights worn by officials while making examinations for gas was recommended only once. It was also recommended once that the use of open and closed lights at the same time should be prohibited.

Dust Control

To render coal dust nonexplosive was recommended 34 times. The chief recommendation was that mines be effectively rock-dusted. Other recommendations made in conjunction with rock-dusting were: that water be applied on the cutter bars of mining machines; that the tops of loaded cars be wetted before the cars are hauled from the working face or side track; that empty cars be wetted before they are returned to the working places; that the face regions be kept wet; and that roadbeds on haulage roads be sprinkled.

Electricity

The increasing use of electricity underground has introduced additional sources of ignition of gas and dust. Investigators have realized this new hazard, and 9 recommendations were made for using permissible electrical equipment which, under normal conditions, is safe for use in gassy or dusty atmospheres. The use of permissible mining machines was recommended 6 times. Investigators recommended the use of permissible (storage-battery) locomotives 3 times. The trailing cable on permissible mining machines is the weakest point of the equipment, hence it was recommended that the trailing cable be examined carefully at regular intervals. Electric wiring and electrical equipment, especially if it is of open type, should be placed on pure intake air. Wiring, especially at the face, should be properly installed.

Blasting and Explosives

Although blasting and explosives caused 94 of the 287 explosions, only 18 recommendations affecting explosives were made. Of this number 9 were that permissible explosives and blasting devices should be used. Recommendations were made twice for prohibiting the firing of open shots and requiring that all charges be placed in properly drilled holes and confined with incombustible stemming. Other recommendations were: That blasting devices be fired in a permissible manner; that miners be limited to one day's supply of explosives; that all persons remain at a safe distance while shots are fired; that shooting off the solid be prohibited; that clay (incombustible) stemming be employed; and that shot holes should not be overcharged.

MINE SAFETY BOARD DECISIONS

The policies of the United States Bureau of Mines regarding safety in mines are governed by the decisions of its Mine Safety Board, which are issued after due deliberation and the unanimous consent of the 5 members. The decisions, if followed, should help materially to prevent coal-mine explosions in West Virginia; they have been issued by the United States Bureau of Mines as Information Circular 6732 and copies may be obtained by writing the bureau at Washington, D. C.

CONCLUSIONS

The leading cause of explosions has been explosives and blasting, followed closely by open lights; 167 of the 287 explosions were initiated by these two causes. Electricity, although ranking third as a cause of explosions, actually now causes the largest number; from 1931-33 electricity caused 68.8 percent of the coal-mine explosions in the coal mines of West Virginia. A more intensive campaign against mine explosions in West Virginia should be directed toward eliminating electrical sources of ignition. During the last 3-year period open lights caused 18.8 percent of the explosions and explosives only 6.2 percent. Open lights are a constant explosion and fire hazard; permissible electric cap lamps should be required in all coal mines, as they are not only safer than open lights from the explosion-prevention and fire-prevention standpoints but are also a means of reducing mine accidents in general.

Many explosions in West Virginia coal mines have resulted from carelessness on the part of the mine management through failure to prohibit open lights in mines known to liberate fire damp; to discontinue use of open and closed lights in the same mine; to use only permissible electrical equipment in mines known to be gassy; to substitute permissible explosive for black blasting powder, whether in granular or stick form; to require thorough examinations by fire bosses before each shift enters the mine; to keep fans running at all times or to ventilate a mine thoroughly after the fan has been started following a shut-down; and to make a thorough examination of the mine before power is turned on in the mine or men are allowed to enter.

For the past few years various agencies and conditions have operated to bring about greater safety in the West Virginia coal mines, and in essentially no phase of these praiseworthy efforts has the result been more successful than in the avoidance of explosions. The results are reflected in the decrease in explosion-fatality rates per million tons of coal mined and per million man-hours of exposure. The decrease in the percentage of explosion fatalities to total coal-mine deaths is largely the result of close cooperation of the coal miners, the coal-mining companies, the West Virginia Department of Mines, the Safety Division of the United States Bureau of Mines, and other agencies in eliminating ignition sources, increasing ventilation, and providing protection by rock-dusting. At this writing, West Virginia has not had a major explosion disaster in its coal mines in practically 2 years, a remarkably good record, and with continuation of the same type of cooperation which has been in effect the past few years among the interested agencies, there is good reason to believe that the good record of the past few years will be definitely bettered in future years.